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ORIGINAL ARTICLE

Socioeconomic status and risk of osteoporotic fractures and the use of DXA scans: data from the Danish population-based ROSE study

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Abstract

Summary There is a need of studies exploring the link between socioeconomic status and DXA scans and osteoporotic fracture, which was the aim of the present study. No differences in socioeconomic status and risk of osteoporotic fractures were found. However, women with further/higher education and higher income are more often DXA-scanned.

Introduction Lower socioeconomic status is known to be associated with a range of chronic conditions and with access to health care services. The link between socioeconomic status and the use of DXA scans and osteoporotic fracture, however, needs to be explored more closely. Therefore, the aim of this study was to examine the relationship between socioeconomic status and both DXA scan utilization and major osteoporotic fractures (MOF) using a population-based cohort of Danish women and national registers.

Methods The study included 17,155 women (65–81 years) sampled from the Risk-stratified Osteoporosis Strategy Evaluation study (ROSE). Information on socioeconomic background, DXA scans, and MOFs was retrieved from national registers. Competing-risk regression analyses were performed. Mean follow-up was 4.8 years.

Results A total of 4245 women had a DXA scan (24.7%) and 1719 (10.0%) had an incident MOF during follow-up. Analyses showed that women with basic education had a lower probability of undergoing DXA scans than women with further or higher education (greater than upper secondary education and vocational training education) (subhazard ratio (SHR) = 0.82; 95% CI 0.75–0.89, adjusted for age and comorbidity). Moreover, women with disposable income in the low and medium tertiles had a lower probability of undergoing DXA scans than women in the high-income tertile (SHR = 0.90; 95% CI 0.84–0.97 and SHR = 0.88, 95% CI 0.82–0.95, respectively, adjusted for age and comorbidity). No association between socioeconomic background and probability of DXA was found in adjusted analyses.

Conclusion The study found no differences in risk of osteoporotic fractures depending on socioeconomic status. However, women with further or higher education as well as higher income are more often DXA-scanned.

Keywords DXA scan · Osteoporotic fractures · Socioeconomic inequality in health · Socioeconomic status · Women

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Introduction

Inequality in health is a major public health concern, and the reduction of socioeconomic inequalities in health is a goal both nationally and internationally [1–3]. Nonetheless, there is evidence of increasing inequality in health [4], and it is well established that socioeconomic inequalities exist in mortality and in a range of chronic conditions, e.g., cardiovascular disease, diabetes, and different cancer types [4, 5]. Likewise, socioeconomic differences have been shown in access to health care and in use of health care [6].

Whether socioeconomic inequalities exist for osteoporosis is, however, less clear. Osteoporosis is a skeletal disorder characterized by decreased bone strength that results in increased risk of fractures [7], and osteoporotic fractures are the most important clinical complication of osteoporosis. Some studies reveal higher fracture incidence and fracture risk among persons with lower socioeconomic status compared to those more advantaged [8–11], whereas others conclude that fracture incidence does not have a social gradient [12, 13]. A systematic review concluded that conflicting evidence exists for the association between socioeconomic status and osteoporotic fracture [14].

Dual-energy X-ray absorptiometry (DXA) is widely used to measure BMD at the hip and lumbar spine and is considered the "gold standard" for identifying persons at high risk for osteoporotic fracture and for monitoring treatment [15]. In Denmark (as in other countries), a case-finding strategy has been adopted, where general practitioners (GPs) are advised to refer persons with one or more risk factors to DXA scan at hospital-based specialized wards with DXA facilities. Denmark has universal coverage of the population with no co-payment for access to GPs and hospitals services. According the national Danish guidelines, co-payment for anti-osteoporotic medication are determined by DXA results unless hip or spine fracture is present. In previous studies, it has been suggested that a relatively high proportion of DXA examinations are performed in persons with a low risk of osteoporotic fracture [16], but it is still not well established whether DXA utilization is associated with socioeconomic status [17, 18].

The study is important for two major reasons. First of all, studies of socioeconomic inequality in health and healthcare utilization are important from a public health perspective in terms of helping secure equity and informing health policies. Secondly, due to the major burden of osteoporotic fractures worldwide, it is essential to have a thorough understanding of relevant predictors and potential risk factors for fractures in order to design targeted interventions. Therefore, the aim of this study was to examine the relationship between socioeconomic background and DXA scan utilization as well as that between socioeconomic background and the risk of major osteoporotic fractures using a population-based cohort of Danish women and national registers.

Method

Design and population

This prospective study included a cohort of women aged 65–81 years living in the Region of Southern Denmark who participated in the Risk-stratified Osteoporosis Strategy Evaluation study (ROSE). The design of the ROSE study and inclusion of the women have been reported in detail previously [19]. In brief, the ROSE study is a randomized controlled trial investigating the effectiveness of a two-step screening program including a postal questionnaire on risk factors for osteoporosis and fractures to enable calculation of the 10-year probability of major osteoporotic fractures based on FRAX. Women in the screening group with a 10-year probability of major osteoporotic fractures above 15% were then offered a DXA scan. The randomization 1:1 into screening and control groups was stratified according to area of residence and age, and the women were included in the study from February 2010 to November 2011. Both groups were posted the same self-administered questionnaire comprising questions about fracture risk. In the present study, we only used data on the control group to investigate the association between socioeconomic status and osteoporotic fractures. A total of 17,157 women were included in the control group. Subgroup analyses included 10,494 women who filled in and returned the ROSE questionnaire (Fig. 1 (flow-chart)).

Variables

Outcome (DXA scan and osteoporotic fractures) and follow-up

At birth, all persons residing in Denmark are assigned a unique personal identification number. This identification number is used across all national Danish registers and may therefore be used to link data from all public registers at an individual level, also to the questionnaire data. In this study, data from the ROSE study were merged with information on DXA scans and fractures, obtained from the National Patient Register (NPR), and information on death and emigration from the Civil Registration System (CRS) to define end of follow-up. The women were included and observed from the day of inclusion (index date = the date we posted the questionnaire) until the end of follow-up, which was determined at an individual level: 10th February 2016, date of the outcome event for the specific analysis (DXA scan or fracture (MOF or hip), subject was censored at first fracture), date of death, or date of emigration.

NPR contains data on all patients admitted to Danish hospitals since 1977. Discharge diagnoses are coded by physicians, and since 1995 have been coded according to the tenth version of the International Classification of Diseases (ICD-10). In the

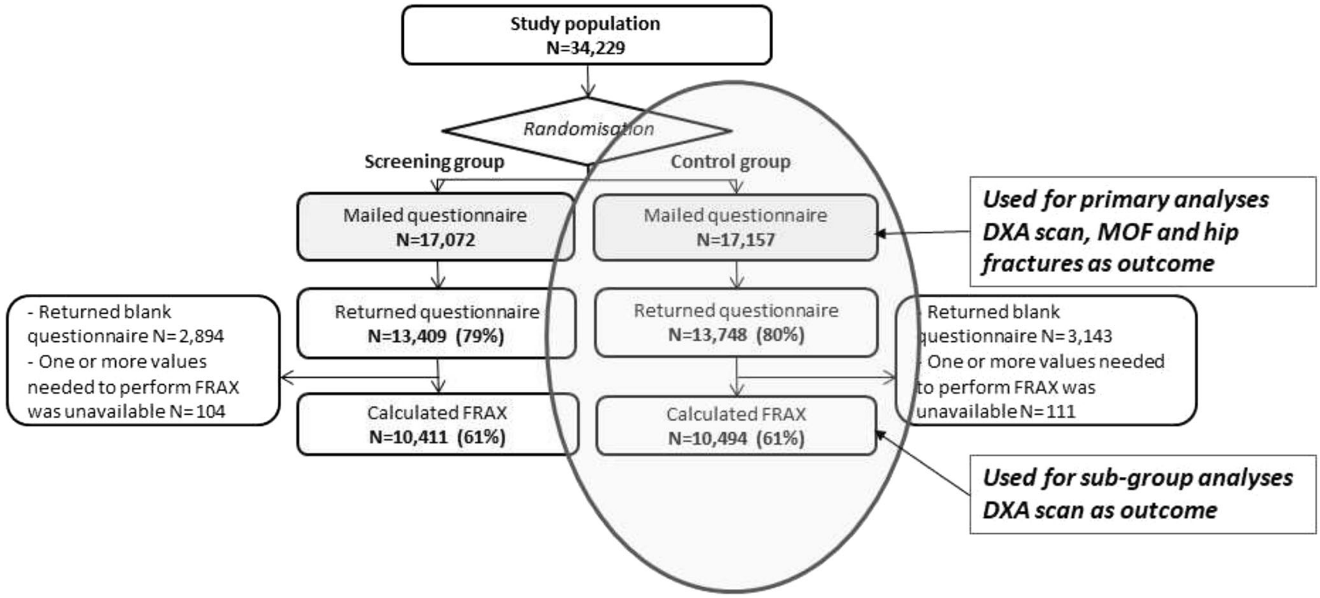

Fig. 1 Flowchart over the ROSE study and groups used for analyses

present study, we extracted data regarding incident major osteoporotic fractures (MOF) (vertebral fractures, humerus fractures, forearm fractures, and hip fractures). The corresponding ICD-10 codes for vertebral fractures are the following: S120, S121, S122, S220, S320, and T08; for hip fractures: S720, S721, and S722; for humerus fractures: S422 and S423; and for forearm fractures: S525 and S526. Incident fractures were defined as fractures occurring between the index date and end of follow-up. Fracture events were calculated as number of persons with a fracture during the follow-up period. Information on DXA scan utilization was also obtained from NPR using the procedure codes UXRE80 and UXRG80. Only information on new (incident) DXA scans occurring between the index date and end of follow-up was included.

Socioeconomic status

Variables on socioeconomic status included information retrieved from different registers extracted on the index date for each woman.

- Marital status was extracted from the CRS (categorized into married/living with a spouse or living alone)
- Data on education was extracted from the Danish Education Register and included information on the highest completed education based on the International Standard Classification of Education (categorized into basic school, vocational or upper secondary and further/higher education (greater than upper secondary education and vocational training education).
- Income was extracted from the Income Statistics Register and included information on average disposable income after tax and interest (includes salary, retirement benefits, welfare payments, remuneration, and company profits) categorized into tertiles (low, medium, high)).
- Income-education was a combination of baseline education and income (as described above). These two variables were combined into five exposure groups: (1) High = high education (further/higher education) and high income; (2) Medium/high = high education (further/higher education) and middle income, or medium education (vocational or upper secondary education) and high income; (3) Middle = medium education (vocational or upper secondary education) and middle income, or high education, low income, or high income, low education; (4) Low/middle = low education (basic education) and middle income, or medium education (vocational or upper secondary education) and low income; and (5) Low = low education (basic education) and low income.

Covariates

A priori relevant covariates that could potentially affect the relationship between socioeconomic background and DXA scan utilization risk of major osteoporotic fractures were defined. Analyses with DXA scans as outcome included age, comorbidity, and other important risk factors for fractures (BMI, history of fragility fractures, parental hip fractures, use of oral glucocorticoids, smoking, alcohol intake, and history of falls). Analyses with osteoporotic fractures as outcome included age and comorbidity, but not other risk factors for fractures as these are expected to mediate the potential relationship between socioeconomic status and fractures.

All covariates were measured at baseline and obtained from the registers and the ROSE questionnaire. The Charlson comorbidity index was used to classify comorbid conditions among the respondents [20] with information from the NPR and categorized into three groups: no comorbidity (= 0), low comorbidity (= 1), and medium/high (= 2). Age at baseline was categorized into three groups: 56–69, 70–74, and 75–81 years. Questionnaire data included BMI (categorized as < = 19 kg/m); history of fragility fractures after age 40 years (categorized as yes/no); parental hip fracture (categorized as yes/no); use of oral glucocorticoids ((categorized into dosage = 5 mg for more than 3 months) (yes/no)); smoking status (categorized as current smoker yes/no); alcohol intake in a usual week (categorized as alcohol intake = 3 units daily (yes/no)), and history of falls with more one fall during the last 12 months, where the falls were not caused by an external factor e.g., impingement or shove (categorized as yes/no)).

Statistical analyses

Descriptive results are presented as median and quartiles for continuous data and as counts and percentages for categorical data. Differences between groups in continuous variables were tested using a *k*-sample median test and differences in categorical variables by using a chi-square test. We investigated time to DXA scan as well as time to MOF and hip fracture as outcomes, and calculated crude incidence rates with 95% Poisson confidence intervals by counting events and determining time-at-risk for all participants between inclusion and event/death/end of follow-up. For time to event analysis, we applied the Fine-Gray extension of Cox-regression to take competing risk of death into account and report subhazard ratios (SHR) with corresponding 95% confidence intervals. For DXA scans as well as MOFs and hip fractures as outcome, analyses were carried out (1) unadjusted, (2) adjusted for age, and (3) adjusted for age and Charlson score. Moreover, subgroup analyses with DXA scans as outcome adjusted for age, Charlson score, and other potential confounders for those individuals who answered the questionnaire were performed as these variables could potentially confound an association between socioeconomic position and DXA scan utilization (Fig. 1).

Sensitivity analyses were performed to explore potential differences in the results when stratified on age (using the age groups 65–69, 70–74, 75–81 years), when categorizing the income into quintiles instead of tertiles, and with “all fractures”' as outcome (ICD-10 codes: S02, S12, S22, S32, S42, S52, S62, S72, S82, S92).

Associations were considered statistically significant at the $p < 0.05$ level. STATA/MP 14.1 was used for all statistical analysis.

Ethics

The ROSE study was conducted in compliance with the Declaration of Helsinki II and was approved by the Regional Scientific Ethical Committee for Southern Denmark (jr.nr S-20090127) and the Danish Data Protection Agency (jf.nr. 2008-58-0035). The study is furthermore registered in ClinicalTrials.gov (NCT01388244).

Results

Complete follow-up was available in 17,155 women, corresponding to 99.9% of the initial population, and included in the analyses. The study had a mean follow-up time of 4.8 years (range 0 to 6.0 years). Among the 17,155 women in this study, 2021 died during follow-up while 30 emigrated.

Table 1 shows baseline socioeconomic characteristics of all women in the cohort. The highest proportion had completed basic school as their highest education level (56%), are married/living with a spouse (57%), and have a low/middle income-education (low education (basic school) and middle income or medium education (vocational or upper secondary) and low income) (31%). The same patterns were seen among the subgroup of women with questionnaire data at baseline (Table 1); however, a slightly lower proportion completed

Table 1 Socioeconomic characteristics of the study population. Data are shown as numbers and percentages

	Total population ($N = 17,155$)	Women with questionnaire data ($N = 10,494$)
Marital status		
Married/living with a spouse	9860 (57%)	6597 (63%)
Living alone	7295 (43%)	3897 (37%)
Education		
Basic school	9537 (56%)	5114 (49%)
Vocational or upper secondary	5054 (29%)	3489 (33%)
Further or higher education	2276 (13%)	1753 (17%)
Unknown	288 (2%)	138 (1%)
Income per year (disposable)		
Low tertile	5779 (34%)	3493 (33%)
Medium tertile	5637 (33%)	3224 (31%)
High tertile	5739 (33%)	3777 (36%)
Income-education		
Low	3866 (23%)	2140 (20%)
Low/middle	5267 (31%)	2987 (28%)
Middle	4191 (24%)	2554 (24%)
Middle/high	2252 (13%)	1574 (15%)
High	1579 (9%)	1239 (12%)

basic school as their highest level of education (49%) and are married/living with a spouse (63%). Statistically significant differences were seen in relation to education and comorbidities as well as age, where women with higher levels of education tended to be younger and have a lower occurrence of comorbidity (Table 2).

In the cohort, 4245 women have had a DXA scan (24.7%), 1719 (10.0%) a major osteoporotic fracture (MOF), and 532 (3.1%) a hip fracture during follow-up (Table 3). A total of 726 women had both a DXA scan and an MOF; and of these, 282 had a DXA scan first, and then an MOF, 443 a DXA scan after an MOF, and 1 a DXA scan and an MOF the same day.

Crude rates of DXA scans per 1000 person-years increased at higher levels of education and income (Table 3). The lowest rates of DXA scans were observed in women with basic school (56.1 per 1000 person-years), unknown education (45.4 per 1000 person-years), and low income-education (54.0 per 1000 person-years). For both major osteoporotic fractures (MOF) and hip fractures, the highest rates were seen among women living alone (MOF, 24.3 per 1000 person-years; hip, 7.8 per 1000 person-years), with basic school (MOF, 23.7 per 1000 person-years; hip, 7.8 per 1000 person-years) and low income-education (MOF, 23.7 per 1000 person-years; hip, 7.8 per 1000 person-years) (Table 3).

The competing-risk regression analyses showed that women with basic education had a lower probability of undergoing DXA scans compared to women with further or higher education both in univariate (SHR 0.84; 95% CI 0.77–0.92) analyses and in the analyses adjusted for age (SHR = 0.83; 95% CI 0.75–0.90) and age and comorbidity (SHR = 0.82; 95% CI 0.75–0.89). This was likewise observed in the subgroup analyses of women with questionnaire data that included adjustment for age, BMI, history of fragility fractures, parental hip fractures, use of glucocorticoids, smoking, alcohol intake, history of falls, and comorbidity (SHR = 0.89; 95% CI 0.80–0.99). Moreover, women with disposable income in the low

Table 2 General characteristics of the study population at baseline with respect to education. Data are shown as numbers and percentages

	Total	Basic school $n = 9537$ (56%)	Vocational or upper secondary $n = 5054$ (29%)	Further or higher education $n = 2276$ (13%)	Unknown $n = 288$ (2%)	p value
Total population ($N = 17{,}155$)						
Age						< 0.001
65–69 years	6570 (38%)	3031 (32%)	2367 (47%)	1081 (48%)	91 (32%)	
70–74 years	5301 (31%)	3050 (32%)	1487 (29%)	678 (30%)	86 (30%)	
75–81 years	5284 (31%)	3456 (36%)	1200 (24%)	517 (23%)	111 (39%)	
Comorbidity						< 0.001
0 (no)	9757 (56%)	5105 (54%)	2909 (58%)	1385 (61%)	176 (61%)	
1 (low)	957 (6%)	553 (6%)	280 (6%)	107 (5%)	17 (6%)	
2+ (medium/high)	6623 (39%)	3879 (41%)	1865 (37%)	784 (34%)	95 (33%)	
Women with questionnaire data ($N = 10{,}494$)						
Age						< 0.001
65–69 years	4663 (44%)	1910 (37%)	1798 (52%)	895 (51%)	60 (43%)	
70–74 years	3261 (31%)	1688 (33%)	1009 (29%)	520 (30%)	44 (32%)	
75–81 years	2570 (24%)	1516 (30%)	682 (20%)	338 (19%)	34 (25%)	
Comorbidity						0.003
0 (no)	6137 (58%)	2881 (56%)	2100 (60%)	1073 (61%)	83 (60%)	
1 (low)	547 (5%)	275 (5%)	179 (5%)	86 (5%)	7 (5%)	
2+ (medium/high)	3810 (36%)	1958 (38%)	1210 (35%)	594 (34%)	48 (35%)	
BMI ≤ 19 kg/m^2	397 (4%)	190 (4%)	135 (4%)	66 (4%)	6 (4%)	0.968
History of fragility fractures[a]	1254 (12%)	638 (12%)	387 (11%)	211 (12%)	18 (13%)	0.267
Parental hip fracture	1473 (14%)	637 (12%)	527 (15%)	294 (17%)	15 (11%)	< 0.001
Use of oral glucocorticoids[b]	338 (3%)	178 (3%)	101 (3%)	55 (3%)	4 (3%)	0.497
Current smoker	1545 (15%)	838 (16%)	480 (14%)	207 (12%)	20 (14%)	< 0.001
Alcohol ≥ 3 units daily	117 (1%)	31 (1%)	44 (1%)	40 (2%)	N < 4	< 0.001
History of falls[c]	785 (7%)	370 (7%)	266 (8%)	138 (8%)	11 (8%)	0.805

[a] After age 40 years

[b] Dosage ≥ 5 mg for more than 3 months

[c] More than one falls on 1 year where the occur without any external impact

Table 3 DXA scans and fractures crude rates per 1000 person-years (95% CI)

	All women (17,155)					
	DXA-scans $N = 4245$ (24.7)		MOF $N = 1719$ (10)		Hip $N = 532$ (3.1)	
	N (%)	Rates	*N* (%)	Rates	*N* (%)	Rates
Marital status						
Married/living with a spouse	2464 (25)	59.1 (56.8, 61.5)	926 (9)	20.1 (18.8, 21.4)	268 (3)	5.6 (5.0, 6.3)
Living alone	1781 (24)	60.1 (57.4, 63.0)	793 (11)	24.3 (22.7, 26.1)	264 (4)	7.8 (6.9, 8.8)
Education						
Basic school	2232 (23)	56.1 (53.8, 58.4)	1029 (11)	23.7 (22.3, 25.2)	352 (4)	7.8 (7.0, 8.7)
Vocational/upper secondary	1341 (27)	64.5 (61.1, 68.0)	458 (9)	19.5 (17.8, 21.4)	109 (2)	4.5 (3.7, 5.4)
Further or higher education	618 (27)	64.9 (60.0, 70.2)	201 (9)	19.8 (17.3, 22.6)	62 (3)	5.6 (4.4, 7.2)
Unknown	54 (19)	45.4 (34.7, 59.2)	22 (8)	17.0 (11.2, 25.8)	9 (3)	6.8 (3.5, 13.1)
Income per year (disposable)						
Low tertile	1398 (24)	57.7 (54.7, 60.8)	607 (11)	22.8 (21.1, 24.7)	187 (3)	6.8 (5.9, 7.8)
Medium tertile	1345 (24)	57.4 (54.4, 60.5)	543 (10)	21.1 (19.4, 22.9)	175 (3)	6.5 (5.6, 7.6)
High tertile	1502 (26)	63.6 (60.4, 66.9)	569 (10)	21.6 (19.9, 23.4)	170 (3)	6.2 (5.3, 7.2)
Income-education						
Low	885 (23)	54.0 (50.6, 57.7)	421 (11)	23.7 (21.6, 26.1)	144 (4)	7.8 (6.6, 9.2)
Low/middle	1283 (24)	58.8 (55.7, 62.1)	530 (10)	22.1 (20.3, 24.0)	168 (3)	6.7 (5.8, 7.8)
Middle	1035 (25)	60.1 (56.5, 63.9)	421 (10)	22.0 (20.0, 24.3)	125 (3)	6.3 (5.3, 7.5)
Middle/high	595 (26)	63.9 (58.9, 69.2)	201 (9)	19.2 (16.7, 22.0)	50 (2)	4.6 (3.5, 6.1)
High	447 (28)	68.0 (61.9, 74.6)	146 (9)	19.7 (16.8, 23.2)	45 (3)	5.9 (4.4, 7.9)

and medium tertiles had a lower probability of undergoing DXA scans than women in the high income tertile: both in the unadjusted analysis (low tertile SHR = 0.91; 95% CI 0.84–0.96; medium tertile SHR = 0.89; 95% CI 0.83–0.96), and in analysis adjusted for age and comorbidity (low tertile SHR = 0.90; 95% CI 0.84–0.97; medium tertile SHR = 0.88, 95% CI 0.82–0.95), as well as sub-group analysis adjusted for age, comorbidity, and other risk factors (low tertile SHR = 0.89; 95% CI 0.82–0.98; medium tertile SHR = 0.91; 95% CI 0.84–1.00) (Table 4).

Analyses using the combined income-education variable showed a tendency of a dose-response relationship, but statistically significant differences were not observed for all categories compared with persons with high education and high income. However, persons with both low education (basic education) and low income had the lowest probability of undergoing DXA scans: (SHR = 0.78, 95% CI 0.69–0.87 unadjusted; SHR = 0.74, 95% CI 0.66–0.84 adjusted for age and comorbidity; SHR = 0.79, 95% CI 0.69–0.91 adjusted for age, comorbidity, and other risk factors) (Table 4).

When examining major osteoporotic fractures (MOF) as outcome, a higher risk of MOFs was observed in women with basic education compared to women with further or higher education (SHR = 1.17; 95% CI 1.01–1.35), and in women living alone compared to married women/women living with a spouse (SHR = 1.17; 95% CI 1.07–1.29) in univariate analyses (Table 5). These differences were, however, not seen in the analyses adjusted for age as well as age and comorbidity (Table 5).

In univariate analyses, women with basic education had a 35% higher risk of hip fracture compared to women with further or higher education (SHR = 1.35; 95% CI 1.03–1.77) (Table 5). Moreover, an increased risk was seen among women living alone than in married women/women living with a spouse (SHR = 1.34; 95% CI 1.13–1.59). As observed in the analyses of MOF, the statistical differences disappeared when adjusting for age as well as age and comorbidity (Table 5).

To explore any differences between the age groups, we performed all analyses stratified on age. These analyses did not change overall conclusion as comparable SHRs for the different age groups were found, both with DXA scans and osteoporotic fractures as outcome (results not shown). The sensitivity analyses categorizing the income into quintiles instead of tertiles did not reveal any new results, nor did analyses with all fractures as outcome (results not shown).

Discussion

This population-based cohort study including 17,155 Danish women aged 65–81 years showed that the use of DXA scan

Table 4 Sub-hazard ratios (SHR) for DXA-scans

	All women (*N* = 17,155)			Women with questionnaire data (*N* = 10,494)
	Univariable analysis SHR (95% CI)	Multivariable analysis[a] SHR (95% CI)	Multivariable analysis[b] SHR (95% CI)	Multivariable analysis[c] SHR (95% CI)
Marital status				
Married/living with a spouse	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Living alone	0.98 (0.92, 1.04)	0.97 (0.91, 1.03)	0.96 (0.90, 1.03)	1.04 (0.97, 1.13)
Education				
Basic school	0.84 (0.77, 0.92)	0.83 (0.75, 0.90)	0.82 (0.75, 0.89)	0.89 (0.80, 0.99)
Vocational/upper secondary	0.98 (0.89, 1.08)	0.98 (0.89, 1.08)	0.97 (0.88, 1.07)	0.99 (0.89, 1.11)
Further or higher education	1 (ref)	1 (ref)	1(ref)	1 (ref)
Unknown	0.69 (0.52, 0.91)	0.68 (0.51, 0.90)	0.68 (0.52, 0.90)	0.82 (0.57, 1.16)
Income per year (disposable)				
Low tertile	0.91 (0.84, 0.96)	0.91 (0.84, 0.97)	0.90 (0.84, 0.97)	0.89 (0.82, 0.98)
Medium tertile	0.89 (0.83, 0.96)	0.89 (0.83, 0.96)	0.88 (0.82, 0.95)	0.91 (0.84, 1.00)
High tertile	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Income-education				
Low	0.78 (0.69, 0.87)	0.77 (0.69, 0.86)	0.74 (0.66, 0.84)	0.79 (0.69, 0.91)
Low/middle	0.84 (0.75, 0.93)	0.83 (0.74, 0.92)	0.77 (0.69, 0.87)	0.85 (0.74, 0.97)
Middle	0.86 (0.77, 0.96)	0.85 (0.76, 0.95)	0.81 (0.72, 0.91)	0.91 (0.79, 1.04)
Middle/high	0.93 (0.82, 1.05)	0.92 (0.82, 1.05)	0.88 (0.77, 1.01)	0.89 (0.77, 1.04)
High	1 (ref)	1 (ref)	1 (ref)	1 (ref)

[a] Adjusted for age

[b] Adjusted for age and Charlson

[c] Adjusted for age, BMI, history of fragility fractures, parental hip fractures, use of oral glucocorticoids, smoking, alcohol intake, history of falls, Charlson

differed by education level and income. Women with basic education had a lower probability of undergoing DXA scans compared to women with further or higher education. A similar result was seen with regard to income. The study did not reveal any association between education, income and marital status, and risk of osteoporotic fractures when adjusted for age and comorbidity.

The present study supports the notion of socioeconomic inequalities in the use of health care services in that we found inequalities in the use of DXA scans, a result supported by Bon and Colleagues [17]. A systematic review from 2013, however, revealed limited evidence for an association between education or income and DXA utilization [18], and no evidence for an association with marital status [18]. It must be noted that the results of the present study cannot be directly compared to previous studies due to systematic differences in populations included, designs, etc.

Most health services in Denmark are free of charge at the point of use, including assessment of BMD with DXA scans. Therefore, the observed socioeconomic inequality in DXA assessment is not due to expenses related to the DXA scan incurred by the woman herself. As stated in the introduction, a case-finding strategy is used, where persons who are suspected of having an increased risk of osteoporotic fractures are referred by the general practitioner (GP) to hospital-based specialized wards with DXA facilities. Other studies have shown a relatively high use of DXA scans in low-risk women and low coverage for women with multiple risk factors [16, 21]. This study further supports the finding that the current case-finding strategy is not working as intended. The reasons for this disparity have not been identified, although one reason could be the fact that greater distance to DXA facilities has been shown to be associated with lower utilization [16]. The proportion of persons with lower socioeconomic status (SES) is often higher in rural areas compared to urban areas, and greater distance is perhaps more of a factor for women with a lower educational level. Another reason could be that women with higher socioeconomic status are more aware of their own fracture risk and the availability of DXA scans, which leads to a greater demand.

Overall, we found no differences in education, income or marital status, and risk of MOF and hip fractures when adjusting for age, which is in contrast with the majority of studies published to date [8–11], but similar to what was found by Syddall et al. and Ong et al., who concluded that fracture incidence does not have a social gradient [12, 13]. It is

Table 5 Sub-hazard ratios (SHR) for major osteoporotic fractures and hip fractures all women (N = 17,155)

	Univariable analysis SHR (95% CI)	Multivariable analysis[a] SHR (95% CI)	Multivariable analysis[b] SHR (95% CI)
Major osteoporotic fractures			
Marital status			
Married/living with a spouse	1 (ref)	1 (ref)	1 (ref)
Living alone	1.17 (1.07, 1.29)	1.03 (0.93, 1.13)	1.02 (0.93, 1.13)
Education			
Basic school	1.17 (1.01, 1.35)	1.05 (0.90, 1.22)	1.05 (0.90, 1.21)
Vocational/upper secondary	0.98 (0.83, 1.15)	0.97 (0.82, 1.14)	0.97 (0.82, 1.14)
Further or higher education	1 (ref)	1 (ref)	1 (ref)
Unknown	0.84 (0.55, 1.30)	0.75 (0.49, 1.16)	0.75 (0.49, 1.17)
Income per year (disposable)			
Low tertile	1.05 (0.94, 1.18)	1.04 (0.93, 1.17)	1.04 (0.93, 1.17)
Medium tertile	0.96 (0.86, 1.08)	0.93 (0.83, 1.05)	0.93 (0.82, 1.04)
High tertile	1 (ref)	1 (ref)	1 (ref)
Income-education			
Low	1.17 (0.97, 1.41)	1.07 (0.89, 1.30)	1.08 (0.88, 1.33)
Low/middle	1.08 (0.90, 1.30)	0.98 (0.82, 1.18)	0.99 (0.81, 1.21)
Middle	1.09 (0.90, 1.32)	1.01 (0.84, 1.22)	1.04 (0.84, 1.27)
Middle/high	0.96 (0.77, 1.18)	0.94 (0.76, 1.17)	0.96 (0.76, 1.21)
High	1 (ref)	1 (ref)	1 (ref)
Hip fractures			
Marital status			
Married/ living with a spouse	1 (ref)	1 (ref)	1 (ref)
Living alone	1.34 (1.13, 1.59)	1.03 (0.87, 1.23)	1.03 (0.86, 1.23)
Education			
Basic school	1.35 (1.03, 1.77)	1.11 (0.84, 1.46)	1.10 (0.84, 1.44)
Vocational/upper secondary	0.79 (0.58, 1.07)	0.78 (0.57, 1.06)	0.77 (0.56, 1.05)
Further or Higher education	1 (ref)	1 (ref)	1 (ref)
Unknown	1.19 (0.59,2.39)	0.96 (0.48, 1.93)	0.96 (0.48, 1.94)
Income per year (disposable)			
Low tertile	1.09 (0.88, 1.34)	1.08 (0.88, 1.33)	1.08 (0.88, 1.33)
Medium tertile	1.04 (1.84, 1.29)	0.97 (0.79, 1.20)	0.97 (0.78, 1.19)
High tertile	1 (ref)	1 (ref)	1 (ref)
Income-education			
Low	1.30 (0.93, 1.82)	1.11 (0.80, 1.56)	1.13 (0.78, 1.63)
Low/middle	1.11 (0.80, 1.55)	0.92 (0.66, 1.28)	0.93 (0.64, 1.33)
Middle	1.05 (0.74, 1.47)	0.90 (0.64, 1.27)	0.93 (0.64, 1.35)
Middle/high	0.77 (0.52, 1.16)	0.75 (0.50, 1.13)	0.73 (0.46, 1.13)
High	1 (ref)	1 (ref)	1 (ref)

[a] Adjusted for age

[b] Adjusted for age and Charlson

important to mention that some of the differences in the results across studies possibly could be explained by differences in measures and categorization of SES including education. Sydall et al., e.g., used age leaving full-time education [12] and Crandall et al. used a four-category variable (high school or less, some college, completed college, and at least some postgraduate education [8]), which is different from the categorization in the present study. Likewise, differences in the distribution of ethnicity across studies could also explain some of differences in results across studies. The proportion of elderly women with other ethnicities than ethnic Danes (Caucasians) in Denmark is low, and our study investigated a random sample of the population, hence only a small proportion of the study will be non-Caucasians. We do not have individual level information on ethnicity in this study, but 96% of the cohort are registered as born to at least one parent who was both born in

Denmark and a Danish citizen. However, in other studies, an association between education and risk of fractures was primarily seen among non-Caucasian women [8].

As shown, a significant proportion of DXA in Denmark is currently performed on women with higher SES, but seemingly similar risk of major osteoporotic fractures. A small overlap of women who had a DXA and a MOF was seen in that a total of 726 women had both a DXA and a MOF, and of these, 282 had a DXA first and then an MOF, 443 a DXA after an MOF, and 1 a DXA and MOF on the same day (in total 4245 women have had a DXA scan and 1719 an MOF). It is a possibility that some of the observed socioeconomic inequality in DXA use is mostly seen in women who have a DXA after MOF. Perhaps women with higher socioeconomic status have a higher underlying risk of fracture that is prevented by the higher number of DXA scans. Due to power issues in the present study, we were not able to pursue this further. Further, it should be noted that DXA, an MOF was measured in the same time-period, and if we want to evaluate the effectiveness of DXA in preventing MOF in relation to SES, we need to construct a different study.

One could also argue that DXA examinations for identifying patients in need of treatment are to no avail and should be substituted by other means of fracture risk assessment such as FRAX. Currently, a number of countries is still using DXA as a means of stratifying at risk patients between those in need of and without need of pharmacological intervention. This strategy is based on evidence from the original efficacy studies [22, 23], documenting effect of pharmacological intervention patients identified using DXA. Moreover, in a recent meta-synthesis, authors found that DXA scans are important in relation to how the diagnosis of osteoporosis is experienced, as the DXA scans are seen as a proof of the diagnosis by making the invisible and non-perceptible body visible [24]. However, it is well known that DXA does not capture the totality of fracture risk on its own, and newer studies have documented a fracture risk reduction for high-risk patients identified by the use of FRAX without DXA for denosumab [25], bazedoxifene [26], and clodronate [27]. This argument is further strengthened by a recent cost-effectiveness analysis on the SCOOP study [28], finding the screening program employing FRAX in addition to BMD to be cost-effective. Though, these calculations are based on secondary outcomes in a trial that did not meet its primary outcome – effect on all osteoporosis related fractures, and should therefore be evaluated with caution.

In the present study, we investigated the association between socioeconomic status and fracture risk at an individual level, where others have looked at the role of area deprivation instead, and with mixed conclusions [13, 29]. An ecological study from Spain found that the wealthiest areas had in fact a higher hip fracture incidence compared to the most deprived areas; however, it was concluded that a higher prevalence of obesity as well as a difference in the age and sex composition in the deprived areas could explain the differences in incidence [29]. The contrary was seen in an English study where a higher incidence of hip fractures in the most deprived populations compared to less deprived areas was seen [30]. It has been suggested that low SES is associated with low levels of vitamin D, which could explain some of these findings; however, this wasn't investigated in the present study [31].

Furthermore, we only looked at socioeconomic inequality in relation to use of DXA scans and osteoporotic fractures; other inequalities related to the course of the disease, including use of medication after diagnosis and risk of death and readmissions as well as the likelihood of attending BMD scans after a fracture, could, however, be present. Kristensen and colleagues concluded in a newly published study that higher education and higher family income were associated with substantially lower 30-days mortality and risk of readmission after hip fracture [32]. Moreover, higher education has been shown to be positively associated with use of osteoporosis drug therapy, also among those who have sustained a fracture [33]. Finally, Ong and colleagues conducted a study among persons attending outpatient fracture clinics, and concluded that patients living in the most deprived areas of Nottingham were less likely to attend their DXA scan appointment [13].

Strengths and limitations

Our study has several important strengths. First of all, it was based on a prospective population-based design, which separates it from the majority, which have used a cross-sectional design, both when investigating osteoporotic fractures [11, 13, 14] and DXA scans [17, 18]. In fact, to our knowledge, this is the first cohort study that has investigated DXA use and SES. Moreover, participants were selected at random from the background population, and information on socioeconomic status, DXA scans and fracture outcome, age and comorbidity was obtained from national registers, minimizing selection bias. The linkage to national registers ensured almost complete follow-up. The registers are considered to be the most comprehensive internationally and with high validity, also in relation to the diagnosis of fractures [34, 35].

Some important limitations must be listed. Variables measuring socioeconomic position included marital status, disposable income, and educational level, and it is debatable whether these are the best indicators for this population of elderly women. Disposable income is for a high number of the elderly women relatively low as it is covered by their retirement pension. It does not include household income, wealth, etc., that could be of great importance in operationalizing their socioeconomic status. For older age groups, material wealth, household income, residential status (e.g., home ownership), and financial assets have been suggested as relevant measures of socioeconomic status [36–38]. However, we used the best indicators available.

Furthermore, our finding could only be generalized to women. We only included women; therefore, the results on fracture risk could not be generalized to men due to gender differences in the causes and course of the disease. Even though the risk factors for osteoporotic fractures are the same for both genders, women are especially vulnerable, and among men, lifestyle-related risk factors like alcohol and smoking, where socioeconomic differences are prevalent, could potentially be of more importance. Likewise, the findings may not be applicable to other countries than Denmark that have different healthcare systems and different socioeconomic structures in the population.

Finally, in subgroup analyses on DXA utilization, there is a possibility of selection bias as it has been shown that non-participation was associated with comorbidity, aging, other risk factors for fractures, and markers of low social status [39]. Though we would argue that in the present study, it would not have affected our main results, which are supported by the fact that the primary analyses that were based on register data showed similar results.

Conclusion

The study did not find differences in socioeconomic status and risk of osteoporotic fractures among women aged 65+ years but demonstrated differences in DXA scan utilization depending on education and income level. Women with further or higher education have a DXA scan more often compared to women with basic school and low income. This study supports other studies that have shown that the current case-finding strategy is not working as intended, due to the higher utilization among women with higher socioeconomic position.

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Compliance with ethical standards

Conflicts of interest S Möller, T Holmberg M Bech, J Gram, JS Tolstrup, KH Rubin have no conflicts of interest. MJ Rothmann has received a speaking fee from Eli Lilly. M Hoiberg is a full-time employee of Boehringer-Ingelheim Norway KS (currently). AP Hermann serves on advisory Boards for Eli Lilly, Amgen, and she has received research funding from Eli Lilly, a speaking fee from Eli Lilly, GSK, Genzyme, Amgen; K Brixen reports other from Merck, Sharpe, Dohme, other from Amgen, other from Novartis, other from NPS, all outside the submitted work.

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